Barriers and solutions for early career researchers in tackling the reproducibility crisis in cognitive neuroscience.

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Huber, Potter and Huszar (2018) assert that the reproducibility crisis is underappreciated in cognitive neuroscience, a field, they argue, that favours "storytelling" over reliable research. They contend that unreliable research should be prevented through a variety of pre- and post-publication initiatives. Here, we comment on the practicality of some of these solutions and barriers to change from an early career researcher (ECR) perspective. We believe that in many disciplines, ECRs are predominantly the workforce and their contributions to the resolution of the reproducibility crisis are hindered by the established academic system. ECRs should be appropriately considered when generating ideas for solutions.

Pre-publication initiatives

Huber et al. argue that the scientific community would benefit from a "stronger filter for reliability" before publication and propose several ways that pre-publication reliability checks can be conducted. Here, we outline these initiatives and consider the potential barriers for their implementation from an ECR perspective.

Replication attempts

As highlighted by Huber et al., the incentive structure of academia may prevent researchers from conducting replication experiments. The 'publish or perish' dilemma may be especially important for ECRs who need to produce a strong publication record to advance their academic careers. We agree with Huber et al.'s recommendation that there should be a publicly available platform for replication attempts of original studies, such as the replications initiative at Royal Society Open Science (Chambers, 2018). ECRs would be encouraged to conduct more direct replications if publication prospects were in sight. However, there are likely instances where ECR research requires "novelty", perhaps promoted by supervisors or academic regulations. We recommend that in such circumstances, ECRs adopt the idea of "replication and extension" of previous findings, where they can contribute their own research questions or design incremental experiments to test novel hypotheses. Although ECRs collaborate with senior

academics on most research projects, support may not always be provided on an individual basis, as many academics may still favour "story-telling" over rigorous confirmatory research. We therefore believe systemic change to be crucial in supporting ECRs with attempting more direct replications. For example, requirements for a PhD could include conducting direct replication studies with attempted publication irrespective of the result (Everett and Earp, 2015). Direct replications, and open research practices, could also be introduced in training courses delivered at an ECR level (and even earlier) where practical support is required.

Confirmatory and exploratory findings

Due to the techniques used in cognitive neuroscience, the potential for researcher degrees of freedom are particularly high (e.g. fMRI; Carp, 2012). Although limiting the reliability of research findings, making use of (undisclosed) analytic flexibility to achieve *positive* results is attractive for all researchers given the emphasis for publication. Huber et al. suggest that, given this flexibility, we should clearly distinguish between those studies that are confirmatory and those that are exploratory.

For confirmatory studies, pre-registration and 'Registered Reports' offer researchers a way of registering research plans prior to data collection. These initiatives are a way of ensuring best practice and, in some cases, guaranteed publications. However, pre-registration of research may not always be suitable for ECRs who are typically time limited and require further training (see Morey & Tzavella, 2018 and Allen & Mehler, 2018). First, ECRs are typically unfamiliar with the subject area in which they commence their PhD studies, or post-doc research. As such, it may be difficult to acquire sufficient knowledge, and to develop new skills (e.g. to use a new technique) as means to perfect plans within a reasonable timescale prior to formal registration. These issues can be overcome in a variety of ways. ECRs should be encouraged to undertake collaborative projects, such as consortia and multi-site replications, and to participate in initiatives such as Study Swap (https://osf.io/574v3/), to make the most of the resources they have. If pursued, ECRs should not be at risk of diluted authorship. Pre-registration of conference posters (https://tinyurl.com/yan53t7e) may also help shape plans prior to committing to formal registration.

Second, once formalised plans are submitted, at least in the case of Registered Reports, it is likely to take time to receive comments from reviewers. This will inevitably further impact ECR's time if these require revisions and further pilot studies. Although changes will likely

benefit the quality of the research project, it is important to recognise the impact that this will have on the quantity of studies that ECRs are able to complete (and publish) in the time frame available during PhD studies and post-doc contracts. While quality should certainly be favoured over quantity, having limited research output at an early career stage may not be conducive to progressing in academia (Allen & Mehler, 2018). We argue that time frames for projects and ECR contracts should be increased, but until this happens, Registered Reports may not be suitable for *all* research projects. As such, ECRs should be encouraged to embrace open science in ways beyond study pre-registration. For example, data sharing, code sharing, producing pre-prints and reporting statistical power for confirmatory hypotheses (Kramer & Bosman, 2017), will also help to improve reproducibility in cognitive neuroscience. It should be acknowledged, however, that training initiatives and resources should be put forward for ECRs, as lack of theoretical and/or practical knowledge regarding open research practices may be a major barrier to implementation at an early career stage.

Open science initiatives, such as study pre-registration, are sometimes perceived as inflexible compared to the long-established practices that have led to the replication crisis (see Munafò et al. 2017). ECRs should be made aware that pre-registering research intentions does not exclude ECRs from reporting transparent exploratory findings. Indeed, Huber et al. state that this is "critical for the advancement of science" and support the use of 'Exploratory Reports' (Cortex; McIntosh, 2017) for publishing such studies. This approach provides a way for ECRs to publish while allowing them to experiment with new and advancing techniques. This is particularly useful in cognitive neuroscience, where there is demand to make use of the most advanced and 'cutting-edge' technology. However, as most research tends to contain both confirmatory and exploratory elements, journals should continue to publish combined studies to prevent salami-slicing (the division of results from a single study into multiple papers; Smolčić, 2013).

Post-publication initiatives

Tracking of reliability

Many ECRs already undertake replication studies and Huber et al. suggest a variety of initiatives that will enable them to make the most of these attempts. Specifically, they recommend tracking reliability of prior publications by linking replication studies to the

original research, regardless of whether or not the attempt to replicate was successful. Citations of replication attempts are likely to increase when linked to the original research, incentivising attempted publication. However, for this to be of benefit, journals must be willing to publish replication studies in the first place and to shift the focus from novel, positive and significant results, to reward well conducted studies with sound methodology. Tracking of work beyond peer-reviewed publications would also be advantageous. We suggest that tracking of replication attempts also take into account non-published research (e.g. preprints) and those with pre-registered methods and analyses. For ECRs especially, this would be a huge incentive to attempt replication studies with potential to gain recognition for their work, irrespective of publication in a peer-reviewed journal, and might help reduce the 'file-drawer' problem (Rosenthal, 1979).

Further, tracking the reproducibility of a study will be of benefit to researchers in general, enabling the rapid assessment its reliability. Huber et al. also recommend that effect sizes and confidence intervals are reported for tracked replications. This, they argue, will avoid uncertainty in "success versus failure". We agree that this addition would prove useful for ECRs (and all other researchers) when weighing-up the evidence they have for research questions and deciding what studies should time and resources be invested in. Collectively, these post-publication initiatives will help to increase confidence in the literature.

In closing, we agree that change is needed to improve reproducibility of research in cognitive neuroscience, but implementing change is difficult. Huber et al. make some interesting recommendations but there are issues that need to be considered for ECRs, such as time-constraints and the need for training and support to participate in open science practices and to pursue replication studies. Solutions to these issues include, but are not limited to: (1) collaborative efforts to make the most of resources available to ECRs and others; (2) encourage ECRs to attempt direct replication studies, and/or those involving replication and extension. ECRs should also be supported in this by their respective institutions; (3) ECRs should be encouraged to engage in a range of open science practices. Collectively these solutions will help to improve reproducibility, while accounting for the barriers to change held by ECRs.

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